INVESTIGATING DOMINANCE IN DOUGLAS - FIR STANDS

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Introduction

Why are some trees larger than their neighbors? Are they older? inherently faster growing? located on a better microsite? or do they receive less competition from nearby trees? Such possibilities come to mind when one views trees of unequal size in young, even-aged stands of Douglas-fir.

The relative size of individual trees, their "dominance," was investigated in three young Douglas-fir stands in 1958-59. Study techniques were designed to measure effects of small differences in age and competition on comparative heights and diameters within groups of trees. Concepts, field and analysis techniques, and findings are herein reported.

Background Discussion

Identifying the factor or factors which permitted a tree to grow taller or larger than its neighbors is difficult. Because dominance must be manifest before it can be studied, one attempts to peer into the past in search of contributing causes. Lack of long-term records limits investigation to those influencing factors detectable for evaluation now. Historical happenings which differentially aided or retarded growth of the subject tree and its neighbors are often permanently hidden from view. Thus, the investigator reluctantly proceeds on the assumption that presently detectable factors have been important influences in the past, and that their relative influence has continued unchanged over a span of years.

Variations in time and conditions of establishment, shrub and tree competition, genetic potential, and microsite quality probably exert major effects on tree size. Since microsite differences may be minimized if trees physically close to one another are compared and genetic comparisons cannot be made in short-term experiments, first interest centers on how cumulative growth has been affected by differences in age and competition within small groups of trees.

This paper is revised from "The Influence of Time of Establishment and Competition on the Comparative Heights of Second Growth Douglas-Fir Trees," a thesis submitted to Oregon State University in partial fulfillment of requirements for the Master of Science degree, June 1960.

Age

So-called even-aged natural stands may actually contain trees with a range of ages.[1/] Depending on the nature of stand establishment, a tree's present greater size could possibly be due merely to an earlier start of one to several years. Increment produced in several additional years of growth and a greater average yearly growth caused by an initial favorable crown and root position may both contribute to greater size. Once dominant in a developing stand, relative height advantage of an individual tree is often maintained or increased (Heck 1925; Warrack 1952). Thus, greater age alone may cause substantially greater tree size, even if all other contributing factors are the same. Conversely, unequal competition among adjacent trees might, in time, cause loss of dominance gained because of a tree's greater age.

Competition

Numerous measures of competition appear in the literature. Number of trees per acre was used to measure density and its effect on expression of dominance in white pine (Deen 1933). A study directed more specifically toward individual tree performance compared height of tallest tree in relation to the number of red pines within a surrounding 20-foot square (Shirley and Zehngraff 1942). To derive a competition factor for individual white and Engelmann spruces, De Grace (1950) included trees within 12 feet of the subject tree and weighted these on the basis of average values calculated for defined volume classes. Ten-year height increment was inversely related to competition as defined by De Grace with a correlation coefficient of 0.69.

In another approach, the theoretical growing space of "subdominant" white pine trees was correlated with their basal-area growth percent (Wojczyński 1932). Radius of the growing space was calculated as the arithmetic mean of the distances from the subject tree to points located on lines to neighboring trees, the point locations being determined by the proportion of subject tree d.b.h. to neighboring tree d.b.h. The high correlation found between basal-area growth and growing space by this method is not surprising, since subject tree size was not kept independent but directly influenced the estimation of growing space.

When competition measures have been kept independent of subject tree size, an area of constant size has commonly been used to represent growing space around the subject tree. But by holding area constant, the variation in space requirements between smaller and larger competitors is ignored. A modified approach, taking size, number, and nearness of competitors into consideration, has produced good correlation with diameter growth of the subject tree (Spurr 1962).

Competitive effects produced by a tree are related to its root and crown spread. Since moisture does

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[1/] "<u>Even-aged.</u> Applied to a stand in which relatively small age differences exist between individual trees. The maximum difference in age permitted in an even-aged stand is usually 10 to 20 years...." "Forestry terminology," 3rd ed., Society of American Foresters, 97 pp., Washington, D.C. 1958.

not move through soil at high moisture tensions, extent of a tree's root system defines the limit of its influence on water and soil nutrients. Likewise, areal shade is related to crown diameter. Both roots and crown are more or less symmetrical around the tree bole, and their extent is closely correlated to d. b. h. (Briegleb 1952; Smith 1964). Therefore, d. b. h. is one easily measured parameter related to the growing space used and the competition exerted by an individual tree during its period of vigorous growth.

The influence of distance between competitors and the maximum distance that competition is exerted also require consideration. In Douglas-fir spacing tests near Carson, Wash., competition began early in stand development. By 10 years of age, trees at wider spacings showed greater height growth (Isaac 1937). Differences between average height of trees at the extreme spacings (4 by 4 and 12 by 12 feet) widened with age. After 33 years, average tree height at 12 by 12 spacing on site IV land was 20 feet, or 53 percent greater than at the 4 by 4 spacing. Average d. b. h. was more than doubled (Reukema 1959). Although this single test shows that Douglas-fir grows larger when given space to grow, it does not define the growing space a Douglas-fir tree of a given size requires under given site conditions to be free of competition.

Methods

Three Douglas-fir stands on site quality III land were chosen for the study. One stand was located on the Voight Creek Experimental Forest near Orting, Wash.; another on the Black Rock Experimental Forest near Falls City, Oreg.; and the third on the Adair Tract north of Corvallis, Oreg.[2/] All three stands were of natural origin and stocking was near normal in terms of stems per acre.

Subject trees used in size comparisons were in groups of four (Voight Creek) or five (Adair, Black Rock) located in 1/100-acre plots spaced about 2 chains apart. The small plot size served to minimize microsite differences between the subject trees. Descriptive data from trees sampled in each stand are given in table 1.

Trees sampled were dominants, codominants, or strong intermediates. Diameter at breast height, height, age, and competition were measured for the subject trees on each plot. Techniques used for the latter two measurements and for data analysis are described below.

Age

Accurate borings for age require penetration through the tree pith at ground level, since age variation increases with height of sampling (British Columbia 1950). The words of Bauer (1924) emphasize that hitting the pith is more easily said than done: "It becomes quite an art to find the center of a tree accurately when a complex of factors act all at once to

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[2/] Appreciation is expressed to St. Regis Paper Co. for permission to study the first stand named; to Oregon State University for permission to study the latter two.

Table 1.--*Description of sampled stands and trees*

Item	Location		
	Voight Creek	Adair Tract	Black Rock
Site index.....................feet..	136	147	125
Plots.........................number..	6	10	5
Trees per plot...............number..	4	5	5
Average d.b.h................inches..	9.6	7.6	10.2
Average range in d.b.h. on plots......................inches..	4.9	3.0	4.7
Average height of dominants and codominants..............feet..	89.2	57.5	81.2
Average height, all trees.......feet..	86.8	57.1	77.7
Average range in height on plots.........................feet..	19.7	10.9	18.2
Average age of dominants and codominants.................years..	45.4	26.5	45.0
Average age, all trees.........years..	45.2	26.6	44.7
Average range in age on plots..years..	4.2	2.3	3.2

shift it from its logical position." Stem and primary root of 1-year-old Douglas-firs together average about 8 inches in length, so a maximum vertical "target" of 4 to 5 inches around ground level was chosen from which to obtain the increment core. Sufficient soil was removed at the tree base to allow turning the increment borer in the target area. The tree pith was then located by test borings made slightly above the chosen spot. Guided by this information, a 5/16-inch core, which penetrated through the pith, was then extracted at ground level.

Rings in the tree center were counted on thin sections cut from the increment core and stained with a differential stain for springwood (Smith 1955). When viewed by reflected light at 20 or 48 X magnification, center rings were quite distinct. Outward from the center, ring counting was easy.

Competition

Because of the strong relationship of root spread and crown width to d. b. h., a "constant times d. b. h." expression was adopted to define a competitor. Three constants were tested: where D is the potential competitor's d. b. h. in inches, competitors were defined as trees closer (in feet) to the subject tree than 1.5D, 1.75D, and 2.0D. For site III lands where the study was made, these constants were estimated to represent a fairly conservative (1.5D) to a fairly liberal definition (2.0D) of a competitor.

Various data for defined competitors were accumulated to express total competition received by one tree from surrounding competitors:

1. Sum of the d.b.h.'s of defined competitors.
2. Sum of the basal areas of defined competitors. This gave more weight than (1) to large competitors since radius was squared.
3. Sum of the ratios resulting from dividing each competitor's d.b.h. (in feet) by that tree's distance from the subject tree. This method weighted data by both size and proximity of competitors.
4. Sum of the squares of the ratios in (3), which further increased the weight given to large, or nearby, competitors.

Data Analysis

Linear regressions and correlation coefficients were calculated to relate height and diameter of trees on each study area to total age, to competition, and to age and competition combined. For analysis, data for height, diameter, age, and competition were first converted to percent of average for each plot and then combined for all plots within a single stand.

Results

Age

Slightly older trees were generally taller and larger in diameter. Correlations of height and diameter to age for trees at Voight Creek and Black Rock proved statistically significant at the 95-percent level or higher:

Stand	Number of trees	Correlation coefficient (r) D.b.h.	Correlation coefficient (r) Height
Voight Creek	24	0.53**	0.42*
Black Rock	25	.40*	.47*

*Significant at the 95-percent confidence level.
**Significant at the 99-percent confidence level.

Range in tree age on plots at Adair Tract averaged only 2.3 years (table 1), too small for meaningful analysis.

For trees at Voight Creek, the regression equation (using adjusted data) relating height to age is $\bar{y} = 100.0 + 1.00\,(x-100.0)$. Thus, a 48-year-old tree in the 45-year-old stand (107 percent of average age) could be expected to show a height superiority of 7 percent or 6 feet over the average tree height of 87 feet. The same tree would be 23 percent or 2.2 inches larger than the 9.6-inch average d.b.h., as predicted from the d.b.h.–to-age equation, $\bar{y} = 100.0 + 3.22\,(x-100.0)$.

Regression coefficients relating height and d.b.h. to age for trees at Black Rock are 1.47 and 2.44, respectively. Thus, for a tree 3 years older than average in this stand, one would predict about 10 percent more height and 17 percent greater d.b.h.

Competition

Height of the subject tree at Voight Creek correlated much better with total competition derived as the

sum of competitor basal areas or ratios than as the sum of d.b.h.'s or ratios squared. Hence, in analyses of Adair Tract and Black Rock data, only the first two expressions of competition were evaluated.

Competition affected diameter and height of trees in the Voight Creek and Adair stands (table 2). Most correlations between competition and d.b.h. for these two stands were significant or highly significant. Some significant correlations between competition and height were also found. No significant association was found between competition and d.b.h. or height of trees at Black Rock.

Regression coefficients relating d.b.h. or height to competition were substantially larger for trees at Voight Creek than at Adair Tract, and in both areas those relating d.b.h. to competition were larger than those for height. When competitors are within 1.75*D* of the subject tree at Voight Creek, d.b.h. relates to competition (data expressed as sum of ratios, adjusted to percent of plot means) as

Table 2.--*Correlation coefficients (r) between competition and observed height or d.b.h. in three young Douglas-fir stands*[1/]

Stand	Competitor criterion	D.b.h. and sum of basal areas	D.b.h. and sum of ratios	Height and sum of basal areas	Height and sum of ratios
Voight Creek	1.5*D*	-0.27	-0.56**	-0.36	-0.36
	1.75*D*	-.42*	-.53**	-.58**	-.57**
	2.0*D*	-.41*	-.41*	-.44*	-.42*
Adair Tract	1.5*D*	-.32*	-.43**	-.20	-.08
	1.75*D*	-.47**	-.47**	-.36*	-.10
	2.0*D*	-.28	-.32*	-.21	-.11
Black Rock	1.5*D*	-.17	-.03	-.02	-.01
	1.75*D*	-.33	-.07	-.04	-.01
	2.0*D*	-.10	-.05	-.02	-.01

* Significant at the 95-percent confidence level.

** Significant at the 99-percent confidence level.

1/ Based on 1 and 22 degrees of freedom for Voight Creek data, 1 and 48 for Adair Tract, and 1 and 23 for Black Rock.

$\bar{y} = 100.0 - 0.95\ (x-100.0)$, and height as $\bar{y} = 100.0 - 0.40\ (x-100.0)$. Under the same competitor definition, but using sum of basal areas because these coefficients are larger, d.b.h. for Adair Tract trees relates to competition as $\bar{y} = 100.0 - 0.27\ (x-100.0)$ and height as $\bar{y} = 100.0 - 0.086\ (x-100.0)$. Thus, a tree with 20 percent more competition than average would be predicted to be about 19 percent less than average stand diameter at Voight Creek but only 5.4 percent less at Adair Tract. Height of that same tree would be 8 and 1.7 percent less than average stand height at Voight Creek and Adair Tract, respectively.

Age and Competition

Multiple regression analyses relating d.b.h. or height to both age and competition were made only with Voight Creek data, since either one or both independent variables were not significant at Adair Tract and Black Rock. The multiple regression coefficient for d.b.h. related to age and the reciprocal of competition was 0.69, for height 0.67. Both coefficients are highly significant statistically.

Discussion

Age

A small difference in time of establishment of the individual tree in an even-aged stand is associated to a surprisingly large degree with the tree's future dominance. Perhaps individuals established first have better opportunity for uncontested root extension, and root system superiority has been suggested as mandatory if a tree is to achieve and maintain dominance (Stevens 1931). Physical damage, such as browsing, frost, or ice breakage, might be expected to obscure the age-height relationship. However, Deen (1933) reported that lateral branches straightened up following removal of 2 years' height growth from selected 17-year-old trees in a nearly stagnated stand of Norway (red) pine so that "At the end of 2 years the loss in height growth by the topped trees was so slight as to be of no practical significance." Such recovery may tend to maintain the initial height advantage gained by earlier establishment in all but extreme cases.

Competition

The empirical measures of competition used in this study proved useful in stands at Voight Creek and Adair Tract but failed at Black Rock. A single value, expressing competition, can be but a rough approximation of a highly complex relationship.

Judged by highest correlations, the best distance definition for competitors was $1.75D$. Since this definition was bracketed by the other two distance criteria, confidence can be placed in its use for stands of this age range and site class. At $1.5D$, competition is apparently underestimated; at $2.0D$ it is overestimated. Smith (1958) has suggested optimum spacing distances of 1.5 by d.b.h. on site 150 and 1.0 by d.b.h. on site 200 for rapid growth of young Douglas-fir. Data from this study indicate these recommendations may be conservative if one wishes to eliminate all competition.

Spurr (1962) has illustrated the greater sensitivity of using both size and distance of competitors in measuring the effect of "point-density" or competition on diameter growth of individual Douglas-firs in New Zealand plantations. In Adair Tract and Voight Creek data, similar gain can be seen by the higher correlations of d. b. h. with the sum of ratios than with the sum of basal areas. Height-competition correlations were greater, however, when based solely on basal area of defined competitors.

Several weaknesses may exist in assumptions underlying the method of estimating competition used in this study. Symmetry and independence of root system were assumed, but these conditions may not always have existed. In closed stands like those sampled, root grafting may reduce the independence of individual tree growth. On steep slopes, horizontal root spread may be asymmetrical, with the elongated axis parallel to the slope. Lack of significant size-competition correlations at Black Rock might be explained by such root asymmetry, since that stand grew on steep ground. In a second assumption, a deliberate attempt was made to develop an estimate of competition independent of subject tree size. But it can be argued that the larger a tree is, the more it may have suppressed growth of competitors. Thus, there may come a time in individual tree development when a big tree will have less competition than a small tree because of its own size rather than the size of its competitors. The above possibilities illustrate that competitor relations may be difficult to express.

The size-competition relationship might also be curvilinear rather than rectilinear as assumed. In this study, height or diameter data plotted against competition values give little evidence for a curvilinear relationship. Likewise, in the Wind River study, a linear relationship is shown for d. b. h. or basal area of the average tree plotted against its spacing in square feet. Height of the average tree also appears linearly related up to the 10- by 10-foot spacing (Reukema 1959). Hence, addition of individual competitor values and analysis of study data by linear regression seem justified.

The squared multiple correlation coefficient (r^2) for Voight Creek data indicates that 45 percent of the variation in tree d. b. h. is associated with age and competition. Since either age or competition alone is associated with 28 percent, the individual effects are largely additive. Data from the other two stands indicate that 22 percent of the d. b. h. variation is associated with competition at Adair Tract, where age influence was negligible; and age correlates with 16 percent of the d. b. h. variation at Black Rock where competition, as estimated, played a minor role. Most of the variation in d. b. h. is due to genetic, microsite, and other unmeasured influences upon the tree. However, variation accounted for by small differences in age and competition appears large enough to merit consideration in selecting superior phenotypes for genetic purposes and in making decisions regarding interplanting and thinning.

Literature Cited

Bauer, Hans A.
1924. Studying tree growth with an increment borer. J. Forest. 22: 298-301.

Briegleb, Philip A.
1952. An approach to density measurement in Douglas-fir. J. Forest. 50: 529-536, illus.

British Columbia Forest Service.
1950. Report of the Forest Service, year ended December 31st, 1949. 141 pp., illus.

De Grace, L. A.
1950. Management of spruce on the east slope of the Canadian Rockies. Can. Dep. Resources and Develop. Forest Res. Div. Silvicult. Res. Note 97, 55 pp., illus.

Deen, J. Lee.
1933. Some aspects of an early expression of dominance in white pine (*Pinus strobus* L.). Yale Univ. Sch. Forest. Bull. 36, 34 pp., illus.

Heck, [K].
1925. Beiträge zur forstlichen Zuwachskunde. Dritter Teil. Forstwiss. Centbl. 47: 370-377, 462-475, 538-552, 583-593, illus. (Abstr. in English by W. N. Sparhawk in Bot. Abstr. 15: 1551, 1926.)

Isaac, Leo A.
1937. Ten years' growth of Douglas fir spacing-test plantations. U.S. Forest Serv. Pacific Northwest Forest and Range Exp. Sta. Forest Res. Notes 23, p. 6.

Reukema, Donald L.
1959. Some recent developments in the Wind River Douglas-fir plantation spacing tests. U.S. Forest Serv. Pacific Northwest Forest and Range Exp. Sta. Res. Note 167, 7 pp., illus.

Shirley, Hardy L., and Zehngraff, Paul.
1942. Height of red pine saplings as associated with density. Ecology 23: 370.

Smith, Diana M.
1955. Comparison of methods of estimating summerwood percentage in wide-ringed, second-growth Douglas-fir. U.S. Forest Serv. Forest Prod. Lab. Rep. 2035, 12 pp., illus.

Smith, J. Harry G.
1958. Better yields through wider spacing. J. Forest. 56: 492-497.

____
1964. Root spread can be estimated from crown width of Douglas fir, lodgepole pine, and other British Columbia tree species. Forest. Chron. 40: 456-473, illus.

Spurr, Stephen H.
1962. A measure of point density. Forest Sci. 8: 85-96, illus.

Stevens, Clark Leavitt.
1931. Root growth of white pine (*Pinus strobus* L.). Yale Univ. Sch. Forest. Bull. 32, 62 pp., illus.

Warrack, George.
1952. Comparative observations of the changes in classes in a thinned and natural stand of immature Douglas fir. Forest. Chron. 28: 46-56, illus.

Wojczyński, Władysław.
1932. Relation between growth and stand density for a biological tree class in pine stands. Rocz. Nauk Rolnicz. i Lesnych (Polish Agr. and Forest Ann.) 27(2): 227-262, illus. (Abstr. in English by D. Dunning in Biol. Abstr. 7: 19327, 1933.)

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Krueger, Kenneth W.
1967. Investigating dominance in Douglas-fir stands. U.S. Forest Serv. Res. Pap. PNW-43, 10 pp. Pacific Northwest Forest & Range Exp. Sta., Portland, Oreg.

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